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ABSTRACT

The state at 3.614-Mev in Cr^{52} was found to have a spin of 5 by low temperature nuclear orientation techniques. It is thus reasonable to identify this state with the spin 5 seniority-four state predicted by Edmonds and Flowers for an $(f_{7/2})^4$ configuration. The angular distribution parameters for the 1.246-Mev γ-ray, connecting this state with the 4+ state at 2.369-MeV, require that the amplitude mixing ratio, $\delta(E2/M1)$, be negative. It is probable that this transition is 3—23% quadrupole.

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I. INTRODUCTION

Recently Wilson and co-workers(1) have reported an exhaustive study of the energy levels in Cr^{52} populated by decay of Mn^{52}. They found several weak transitions and evidence for several previously unreported energy levels. Of particular interest is a level which they established at 3.614-MeV. This level is depopulated by a 1.246-MeV γ-ray in 5.8% abundance relative to the strongest transition at 1.434-MeV. These authors were able to show that the 3.614-MeV level has character 5+ or 6+. In view of the theoretical significance of this level, it is worthwhile to be able to decide between these two assignments. We report herein new experimental evidence which establishes the spin as 5.

II. EXPERIMENTAL

Some time ago we performed thirty-six adiabatic demagnetization experiments on the nuclear orientation of Mn^{52} in a single crystal of cerium magnesium nitrate. The experiments covered the temperature range 0.003 - 1°K, and were done with axial polarizing magnetic fields in the range 0—800 gauss. Although large spatial anisotropies were observed for the prominent γ-rays, the spectrum in the neighborhood of 1.246-MeV was not plotted. On plotting the entire spectrum, we have now found a clearly discernable peak at this energy in the axial spectra at the lowest temperatures. This is easily explained. In the singles spectrum at ordinary temperatures, the radiation pattern is isotropic and the 1.246-MeV γ-ray lies in the "valley" below the prominent 1.434-MeV photopeak, and is obscured. When the Mn^{52} parent nuclei

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are oriented at low temperatures, however, the intensity ratio I(1.246)/I(1.434) is enhanced by a factor as large as 5 along the crystalline axis because of the greatly different F-coefficients of the two γ-rays.(2,3) This situation is illustrated in Fig. 1. Also shown in Fig. 1 is a pronounced change in the photon anisotropy at about 0.85-MeV. We associate this with the 0.847-MeV γ-ray which connects the 3.614-MeV state with the 2.766-MeV state.(1) This latter state has 4+ character (as does the 2.369-MeV state) and the anisotropy of the 0.847-MeV γ-ray is about the same as that of the 1.246-MeV γ-ray. Thus the interpretation for the 0.847-MeV γ-ray is qualitatively the same as that given below for the 1.246-MeV γ-ray.

A spin of 6 for the 3.614-MeV state may be ruled out immediately by inspection. Wilson, et al.,(1) have measured the conversion coefficient $\alpha_K(1.246) = (7\pm4) \times 10^{-5}$. Thus this transition is mostly dipole and/or quadrupole. If the spin of the 3.614-MeV state were 6 the angular distribution of the 1.246-MeV γ-ray would be essentially identical to that of the 1.434-MeV γ-ray.** It follows from the very great difference in the angular distributions of the two γ-rays (even the signs of the anisotropies are different) that the spin of the 3.614 MeV level is not 6. The spin must then be 5, the only other alternative.(1) (We note that independent of the arguments presented in reference 1, our experimentally derived values of the F coefficients for the 1.246-MeV γ-ray, presented below, eliminate spins of 0, 2, 4 or 6 for the 3.614-MeV level.)

In Table 1 we have listed the measured values of the coefficients X_2 and X_4 in the angular distribution functions(2) for the 1.246- and 1.434-MeV γ-rays,

$$W(\theta) = 1 + X_2 P_2 (\cos \theta) + X_4 P_4 (\cos \theta),$$

for several of our experiments. The first three columns in the table give the run number, the temperature, and the strength of the polarizing magnetic field, respectively. Columns four and five list the quantities X_2 and X_4 for the 1.246-MeV γ-ray and columns six and seven the corresponding quantities for

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** This well-known feature of angular distributions is a consequence of the fact that both transitions would be "stretched" quadrupole transitions.

Table 1. Experimental angular distribution parameters for the 1.246-MeV and 1.434-MeV γ-rays emitted by Mn^{52} oriented in a single crystal of cerium magnesium nitrate.

Run No.	$1/T(^{\circ}K)^{-1}$	H(gauss)	1.246-MeV γ-ray		1.434-MeV γ-ray		Derived F's	
			X_2	X_4	X_2	X_4	$F_2(1.246)$	$F_4(1.246)$
20	179	200	+0.89	+0.02	-0.48	-0.05	+0.75	+0.01
25	174	400	+0.93	+0.08	-0.52	-0.11	+0.72	+0.16
33	100	800	+1.11	+0.02	-0.49	-0.12	+0.91	+0.03

the 1.434-MeV γ-ray. The last two columns give the derived values of F_2 and F_4 (the F's are contained in the X's) for the 1.246-MeV γ-ray, obtained by direct comparison of the data in columns four through seven.[†] These values are $F_2 = +0.8 \pm 0.2$, $F_4 = +0.1 \pm 0.1$, where the error limits are assigned on the basis of the consistency of the data. This range of F_2 requires that the amplitude mixing ratio, $\delta(E2/M1)$, be negative. Gamma-ray multipolarities in the two ranges 3—23% and 64—89% quadrupole would fit the experimental F_2. The first would require F_4 to be in the range $+(0.02—0.13)$, which is in agreement with our result, while the second requires F_4 to be $+(0.36—0.50)$, which does not agree. Thus, while this is less certain than our other conclusions, it seems probable that the 1.246-MeV transition is 3—23% quadrupole.

[†] The reader is referred to references 2 and 3 for discussions and tabulations of nuclear orientation and the F coefficients, respectively.

III. DISCUSSION

The energy levels of Cr^{52} have been discussed, in the light of various theoretical work, by Wilson, et al.(1) The reader is referred to their discussion and to Fig. 11 of their paper, as well as to Fig. 2c of the paper by Edmonds and Flowers.(4)

The 3.614-MeV level in Cr^{52}, whose spin we have established as 5, may be identified with the 5+ seniority-four level predicted by Edmonds and Flowers(4) on the basis of a shell model calculation involving only the configuration $(f_{7/2})^4$. There are four states of seniority four with spins 2, 4, 5, and 8. Wilson, et al.(1) have identified the states of spin 2 and 4 with observed levels, and have tentatively assigned the predicted spin 5 state to the 3.614-MeV level. Our work supports this last assignment. We note, following these authors, that for a range parameter (a/a_o) (Ref. 4) of somewhat less than 1.4, the relative spacing of these seniority-four levels is reproduced quite well. However, in view of recent ideas involving collective vibrations in nuclei such as Cr^{52}, it is perhaps not surprising that the fit of Edmonds and Flowers' level scheme is worsened for states of seniority different from four when (a/a_o) is thus adjusted.

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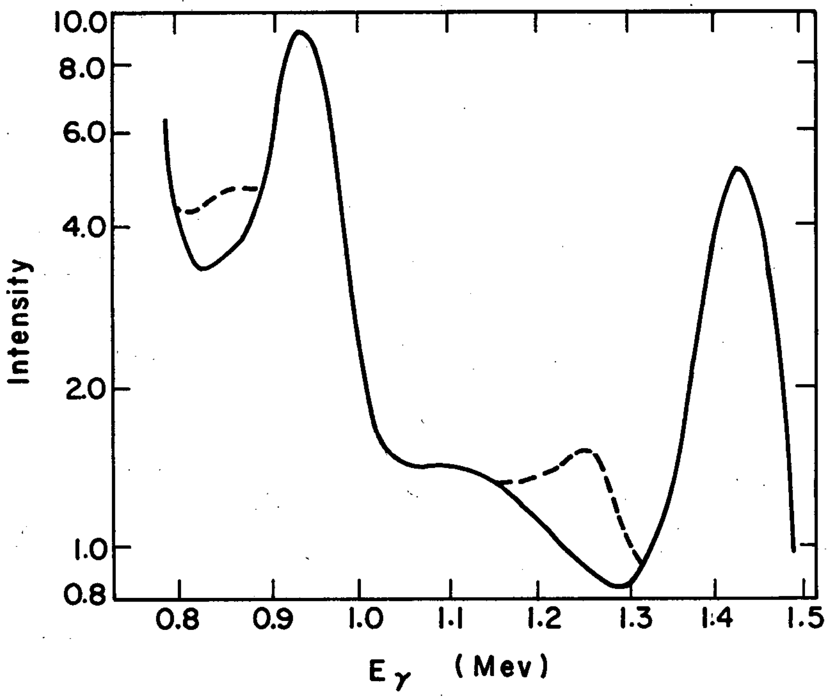

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Fig. 1. Gamma-ray spectrum at 0° from the crystalline c-axis of a cerium magnesium nitrate crystal, containing Mn^{52}, in an axial magnetic field of 200 gauss. The solid curve is the spectrum taken with the crystal at 1°K and the nuclei randomly oriented. The dotted curve is the spectrum taken at 0.0051°K, with the nuclei oriented. This curve has been normalized to the solid curve. (It has only 0.4 the intensity of the solid curve, unnormalized, because of the large γ-ray anisotropy). The two curves coincide everywhere except in the .85 and 1.25 MeV regions, where γ-ray peaks are clearly resolved in the 0.0051°K spectrum.